Bruno Siciliano

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Interviewer: Where you grew up and went to school?

Bruno Siciliano: Yes. Okay, so should I start anytime?

Interviewer: Yes.

Bruno Siciliano: Okay, I was born in Naples, which is the third largest city in Italy, this was 50 and some years ago, October 27, of 1959. And I just recall a funny thing that the ICRA 2009, which is our flagship conference in-- took place in Kobe, it was-- we found out there is a group of us, who were born in 1959, so there's a number of roboticists who are, except me, known in the community just remember some names, Roland Siegwart from ETH Zurich, Peter Corke from Australia, is another '59er and Antonio Bicchi from University of Pisa is another one, and so Roland prepared some kind of nice piece to wear with the logo of the Robotic Society of IEEE and '59er, so this looked like a good year for robotics. And as a matter of fact, 1959 was also the year when the first industrial robot designed by George Devol, was made, was manufactured by Unimation, which is the company, one of the pioneer industrial robot manufacturers in US, so there must be some conjecture about-- around that year, that it was quite funny to discover years after. I did my studies here in Naples, I studied the so-called scientific high school at the Lyceum and then I enrolled into EE Electronic Engineering program here at the University of Naples, Federico Secondo where we are meeting, where I'm speaking this afternoon, and I did my-- at that time, our university system, we only had one degree, which was a five year degree, which is the equivalent to the Anglo-Saxon Masters. And I completed my studies actually in four and a half year, and then I was ready to-- just to leave and probably to move to northern Italy to work for one of the big companies like IBM, Italtel, all the companies in IT having a degree in electronic engineering. And then I had a sort of inspiration, because I got a proposal by a professor, a professor I graduated with, to start the PhD, which is called a Research Doctorate. A Dottorato Research in Italy. This was something new into the university system. Before 1982, we had no PhD, so the highest degree was a Master <Speaking Italian> and the interesting thing was, there was another professor in this department, was being my mentor to robotics, Professor Lorenzo Sciavicco. and at that time, he was just starting doing research in robotics. And myself, having been fascinated by a lot of teenager time readings on the books of Isaac Asimov, about you know, science fiction and robotics, I said robotics, to me, looked so diverse from the classical engineering, and I decided to join the program, because I was fascinated by the new field. At that time, Robotics was still in its infancy in terms of research. Robots were already popular in manufacturing plants, but it was a new field for research. And so I did, I started doing my studies in robotics. And my dream was also to go and do some studies and research in US. And at that meeting, which was the Romanci

Conference, [ph?] which was a sort of mind storm in the history of robotics conferences worldwide, I had the opportunity to meet many distinguished scientists in our field, starting from Professor Bernard Roth, Bernie Roth at Stanford. And then I met also one of the most-- one of the brightest minds that we have in robotics worldwide, and I'm speaking about the coordinator of this project, Professor Oussama Khatib, Oussama, my-- probably, I think is my best friend, and since our first encounter, we became very, very close, very friends, very much friends to each other. And I had the opportunity then to go and spend one year at Georgia Tech in Atlanta, and I worked with Wayne Book, who was one of the distinguished scientists attending this meeting. And this really changed my life, because it opened up my mind, and I also, during the year there, I had the opportunity to travel in US, and visit other labs, and-- but more importantly, I started building my network of contacts, which has helped a lot, you know, during my professional growth. So I finished my PhD, and then it was time to make a decision. And I was very tempted to move to the US. I was offered a position as an assistant professor by Georgia Tech, and it was hard for me to say-- to drop this opportunity because, at that time, I was nothing here, because I had finished my PhD, my grant had finished, and that time, there were no post doc positions available into our university system, and I have to say that I was starving, and the only reason why I could stand it, because I was like a Mama boy, because I was living with my parents, and so I had no major expenses, so I could afford the luxury of doing research as a hobby, without money, without needing money. And so I waited. I was close to a position at Stanford, later in 1989, but there was-- time was right for a position here as an assistant professor in 1989, and I just ran for the position and I got it, and two years later, I became an associate professor, and eight years later I became full professor and after three years, I was hired at the University of Salerno as professor of automatic control, in 2003, I came back to my alma mater, to the University of Naples, Frederick II, Federico Secondo and here I am, and I direct the PRISMA Lab which is the lab doing work on robotics for industry and services, mechatronics and automation. In the meantime, I had cultivated all my international contacts, and I became quite actively involved into the Robotics Automation Society of IEEE. I've served the Society in many ways, I've been on the editorial board of Transactions, and _____ in 1991, and then I became a NATCO member, a member of the Admissory [ph?] Committee, in 1996, and in 1999, I was appointed to replace someone as Vice President for Publications. And then I was elected as Representative for Technical Activities and the apex, I think was in October 2005, when I was elected to President Elect of the Robot and Automation Society of IEEE, and this was almost like a dream come true, because I had just gone through all the steps of the society from a simple member to senior member, I had been elected to fellow, in 2000, and so this was like, kind of, I should say the culmination of my professional service to the society. And so I was President in 2008 and 2009, and I'm now, despite my, I assume, younger age, kind of retired, because I'm-- now my function is a Junior Past President so I continue to serve the Society with the nominations. At the next two years, I will become Senior Past President which means that I will be in charge of the awards, all the awards that our Society gives to-- to the excellence in our field, both in conferences and publications and of course in the

professional achievements. So this is, in a few words, my story around robotics. And I'm just thinking about, I don't have the book with me today, in my office, but there was a quite interesting book that came out in Italian, I don't have a copy here in my office, because I just got it home last week. And this book is called <Speaking Italian> Literally it's like Galileo's nephews. It was written by a science journalist who is quite well known in Italy, and I was flattered to be invited as one of his, ideally, seven nephews of Galileo, and he chose me for engineering, so-- and there are famous scientists, Italian scientists, one of them for all these-- Giacomo Rizzolatti, who is a famous neuroscientist in University of Parma, and I was simply flattered that I was invited. And I was reading this book with my kids last weekend, because just I got it, and I was almost moving to tears because this journalist came to interview me and I told him about all my life and the result was a nice blend between my personal life, almost like kind of biography of the first 50 years of my life, and at the same time, you know, the 25 years of my professional growth merged with the growth of robotics in the field. So it was-- I like the result very much and I mean, it's a nice moment that I could share with my family. And of course I gave the copy to my mother, which, I mean, as you may mention, you know, she was kind of proud of her kids, you know. So this is in a few words, like, my growth as a professional, which I've only been-- I've really been fascinated by robotics. Robotics has been playing a big part in my life, and I think I'm lucky and privileged that-- for the fact that I have, besides a number of colleagues and professionals in this field, I mean, this community is like-- is a big family and with many of the distinguished scientists and colleagues, you know, there is a strong friendship which really gives that extra passion and devotion to this field, so it's--

Interviewer: So part of your PhD work, were you working at electrical engineering or mechanical engineering or were they sort of mixed together?

Bruno Siciliano: This was electronic. The PhD was tied to, I think electronic engineering like my masters, but clearly, working in the field like robotics, I discovered that my background was solid in terms of the mathematics and physics, which typically one studies in doubly, [ph?] but I was lacking in mechanical engineering and so I always liked to take challenges in my life, I like to just be on the edge, and when it was the time, when it was time to go to the US during my third year of my PhD, the challenge was to go to a mechanical engineering school, and I knew very little mechanics, because simply I had not taken enough courses in mechanics and so when I was working under direction of Wayne Book in the School of Mechanical Engineering at Georgia Tech, was also a growth for me, because I learned a lot about mechanics, and after all the years, I discovered that it was not even enough, because robotics was evolving in the meantime and I had to learn about sensor technology and recently I had to learn a lot about cognitive systems, and AI because robotics is becoming more and more a kind of complex and intelligence systems, and I think that nowadays, robotics has reached a level of maturity that the core methodologies and technologies are well developed. Now to further evolve, we need a lot of interaction with fields that until a few years ago, were probably considered to be really

away, apart from robotics, but I think now, I mean, it's the time to reach those crossroads between robotics and all the other fields, and I think further progress will be by, I mean, our attitude should be one of openness and really enlarging our field of interest toward disciplines which, once were considered to be separated from robotics. So this sort of cross fertilization among different fields is happening, and I think robotics is playing a very active role into this process.

Interviewer: So the year you were at Georgia Tech, so what year was that, and what project did you work on?

Bruno Siciliano: I was actually granted by the-- at that time, they had a center which was called Center For Integrated Manufacturing Systems, CIMS, and the emphasis there was on automation, but my actual interest was to work on a new type of robotic system, of robotic manipulator that were becoming very popular. Those were flexible, flexible in the sense of distributed flexibility on the links. So compared to the classical rigid and bulky industrial type of robots, this was a sort of innovation, because flexible manipulators, Dr. Book had been working on flexible manipulators with NASA, with a project with a long boom, the long remote manipulator system used in the Space Shuttle Program, where the flexibility was induced by the length of the arms. Because this big arm, this big boom was supporting a platform where the astronaut would sit, but then flexibility was also used on purpose in the design to make lighter arms, and at that time, it was not clear at all, the enormous potential of this kind of design solution for the future application of robotics. At that time, flexibility was only meant to reduce the load of the structures, of the structure versus the payload, because typically a NASA robot can lift-- to lift a payload of ten kilos, must weigh 200 kilos. And the reason being that it must be accurate. So for precision, for accuracy, you need a very rigid and heavy structure. But thanks to the progress in the latest years on materials science and technology, we've been able to design lighter and lighter arms by using composite materials, carbon fibers and all the like. But recently these lightweight arms have become more and more challenging because the field has evolved and most of the research nowadays is on the so-called problem of human-robot interaction. So if you want a robot to share the space, the workspace with humans, you must go into safety, and safety doesn't come for free. If you have a heavy and bulky rigid arm, because a rigid arm can hit someone and can hurt and can even kill someone, so the trend into the field is to design so-called compliant arms, so arms that will be lighter in terms of the absolute weight, but also arms which, if accidentally in contact with a human, would cause less damage. And so nowadays, like, the mechanical designers are realizing light arms, there's one arm that was designed at the DLR, at the Institute of Robotics and Mechatronics, Professor Eutinger, [ph?] DLR, was a kind of revolutionary arm, because it only weighed 14 kilos to lift up a payload of 13 kilos. We've been using this arm into one of our UPM project. This was the France project where the issue, the attention was on the physical human-robot interaction, dependability and safety. But design is not enough. You also have-- you also have to rely on sensors and on intelligence, on control. So basically

design lighter material are a sort of passive safety measure, but you also have-- you also need some active measure and you gain active safety by designing control algorithms [ph?] which are very fast, and in the case of an accidental contact with a human, are also able to retract the arm and not to cause any damage, any hurt into the human. So that the robots of the future will naturally be compliant both passively and actively, thanks to sensor and control and intelligence.

Interviewer: So what was the first robotics project you worked on, I assume before Georgia Tech.

Bruno Siciliano: Ah, this-- actually this was, during-- it was a project at Georgia Tech, because most of the research I had been doing during my first two years of my PhD, were like, I would say on basic robotics. Also with a background in control, I was working on robust inductive control but mostly at a theoretical and a simulation level, because at that time, I had no lab, I had no experimental setup, so I was working on a theory, so to speak, because, with a strong background in mathematics and control. So my first exposure to hardware, and I was very worried when I went to Georgia Tech, because I was not-- I've never been a good experimenter. As an engineer, I have-- when I started doing my studies in _____ engineering, I had no passion whatsoever for the hardware. I was more attracted by the scientific aspects behind electronic and the novelty of the field. So when I went to Georgia Tech, I had to get my hands on some experimental setup, and the first project was called RALF. RALF stood for Robotics Arm Large and Flexible. And this was a project being developed at Georgia Tech by Wayne Book, and I got to work in that project. And since then, I was involved into other projects in Italy. We worked also on some space robotics project, mainly with the European Space Agency and the Italian Space Agency, and this was a natural follow up because of my expertise on lightweight flexible arm, because flexible arms were being used to use the payload of the space missions. So-- and then I started working on-- or I think the first big project was, as I said, France, in which-- I mean the France is about physical and robot interaction. This was the first big funding that we got from the European Commission. And since then others have followed. I'm currently the coordinator of DEXMART, DEXMART is a large scale integrated project sponsored by the European Commission and it's about dual arm, dual hand, so these are called bimanual manipulation, so robots with two arms and two hands. And this project is about at the end. It will finish January of 2012, and so this is another project. And more recently, I've got interested into aerial robots, flying robots, and I currently have one project which is called iRobots, and there is another one starting in November which is a sort of innovation in the field because it will be multiple cooperating robots flying and manipulating some object and this is like a kind of innovation in the field, because flying robots have been used for several years, but only for patterning, for inspecting fields, coasts, you know, grounds unreachable areas, but the novelty of this project is that they will fly and manipulate, so it's combining the concept of robotic manipulation and take this into the air with a lot of easy problems-- difficult problems, I

mean, easy to understand in terms of communication and _____ operation of these robots and also from a control viewpoint. I have a control background of controlling them and controlling the manipulation while they are flying. And this is posing a lot of challenging issues which-- this is attracting a lot of students, because it's kind of challenge. We have some flying robots in the lab, and the students, they have started to have some fun since a few months. And I think it's one field where we will see considerable progress, and also there is-- there are a number of applications where any robots might be advantageous compared to the classical ground mobile robots, because of the immediate accessibility of flying robot, but of course the regulation in the field are quite strict and severe. I was told by some Japanese colleagues that they were not allowed to operate flying robots in the Fukushima plant because of strict regulation barriers, and they were only able to operate some mobile robots to inspect the plant and to check the level of radioactivity after the disaster, the contamination. But there are a number of applications where I think air robots would play an important role.

Interviewer: So when you came back from Georgia Tech, to-- you came back to Naples, what year was that?

Bruno Siciliano: This was 1986, and for some bureaucratic reasons, I had to wait until '87 to defend my PhD thesis, because this was a new program, as I was saying earlier, into the university system, and so the graduation was delayed, you know, with no explanation, by a few months and then I was officially without a position-- I mean, nominally I was considered as a post doc. I remember one episode which is narrated into this book that I mentioned. This was very funny. One night I was working until late as usual, because I was not many of the time, and laptops, portable computers, I mean, laptops were not yet popular, so I was working on a desktop in my office and to work, I had to be in my office until after hours, and the security guard would come every night, past eight to close the building, and he would always find me working, and I, because with my white hair that I had since a young age, he would call me, Professor. I was nothing, because this was after my PhD, and I had no official position into this building, the building where we are talking this afternoon. This was a room opposite to the hallway from here. And that night there was a colleague, a real professor, working after hours, and the guard came to me and said, "Do you know this guy?" "Yes, of course, he's Professor DiMaria, [ph?] I know him, I know him well." And so he went to this guy and said, "I don't know you, but Professor Siciliano say that exception, you're allowed to stay because he knows you." He was furious, he went mad. I mean, he was yelling at the guard, it's like he is nothing, he has no right to be in this building, he is a clandestino, he's a clandestine. This was quite funny, well funny-- the day after I had a hard time with the department head, because I had to clarify, to clear up my permissions, because I had gained a permission because on my fame of working after hours with this security guard. But this was a time which wasn't easy, because I had refused offers to go to the US, and also I got an offer to go to Tohoku University in Sendai, which I refused. In a way, I have to say that I've always

liked-- I like traveling a lot, and I have many colleagues and friends all over the world. And I love traveling and I love seeing them and I'm often on travel. But I feel attached to my roots, more than I thought initially when I wanted to leave the city and go to work for one of the companies in northern Italy. I think I am attached to my roots, to the city of Napoli, and also to my university. I feel this, and now at this stage I feel even stronger. So I-- when I had _____ it was good for me, it was important to have the opportunity to leave, because then you have a freedom of choice, and you know, when I was considering position in US universities, American universities, I was very tempted. But then I decided that I've had many, many friends and colleagues from my university time, who moved to the US, like brains who have emigrated, and they admitted they had made up a academic career, and you know, colleagues a professor at UCLA, at Berkeley and in other fields, but I decided that I wanted to do this in Naples, and I think it was kind of big bet and a big challenge and despite all the fickleties [ph?] of working in this city, which is not an easy place where to live, because of bureaucratic drawbacks into the Italian system, and also because of different concepts. In a way I'm considered like a kind of a visionary in the sense that I am a workaholic person and I work and I like to reach higher and higher standards, and sometimes people come to me, like, what for, you know, like, because the system is not really encouraging you, motivating you to do this, because professors in Italy are state employees so my salary is the same as the salary of any professor of my age and my seniority, so you know, I've done all this, if you wish, for the glory, for the beauty of doing research at-- I think at the worldwide level, and so this costs me something, but if I have to make a balance now, which is half of my life, I can say so. I'm happy that I stayed in Naples that all that I've reached, I have done with-- in my hometown. I think there's an added value to this, and this will be also a heritage, I think for my kids to attend this. And, I don't know, on one hand I wish that they would leave, or I'm trying to inject a sort of international attitude into their-- well they are still young, but on the other hand, I think it's good, you know, I-- they grew up here with all the good and bad, and the values that we have in our country and our society, and I think in our-- in my hometown, which is suffering from a lot of problem. Naples is often in media for problems with the garbage, with crime and that's the typical stereotype, but despite all this, I think it's-- I think it's a great place and also in terms of the-- I have to say the humanity of the people, is quite unique compared to many other places around the world. And I think the added value for me of having stayed here, and having achieved whatever I've done in my hometown with my alma mater, with my university, I'm kind of a little proud of this, and I think that in the end, it was difficult for me when I was younger, to resist the temptation of leaving, but at this point in my life, I'm happy that I stayed here.

Interviewer: So tell me a bit about how robotics has evolved in Naples. So you have one of, probably the first PhDs in _____ robotics. What were the first labs that opened, and what kind of machines did they have, and what did they--

Bruno Siciliano: Yes. This-- the lab that I'm going to direct is called the PRISMA Lab. This, if I remember correctly, was started in, I think in 1992, 1993. At that time, we were lucky that we had big funding of-- in basic research from CNR. CNR is National Research Council and from 1990 to 1994, there was a huge project in Italy which was called <Speaking Italian> and thanks to this project, there was also a lot of funding on the labs, on the infrastructures. And we were lucky that thanks to the big funding from the CNR, we got the PRISMA Lab opened. At that time, and this was a time of making decisions, because my mentor to robotics, Professor Sciavicco, was the head of the group at that time. I was already an associate professor. I had big discussions, not really argument, discussions with him, what kind of lab should we start, because on one hand, I'd been fascinated by the advanced robotics lab that I'd seen around the world, where it would see no longer industrial robots, but prototypes, innovative robots, be them like advanced robot arms, mobile robots, a lot of work on sensors, and intelligence already, and to me, it was, whereas being a kind of a solid well rounded engineer himself, Professor Sciavicco, he wanted to follow a sort of bottom up approach, so he wanted to start on the safe side with industrial robots because he was convinced of the need of doing some research very close to the technology. And to do some research which could be transferred to the industry without going too far beyond. So there was a big discussion. In the end, he convinced me, because he was worried about starting something too futuristic. Having been no robotics, no lab in Naples before us. So and then we started with this sort of bottom up approach, and I'm happy to see now that I think this was a good choice, because I think it was the way to get-- to gain experience, and also to gain credibility with all the companies in Italy, starting from the big robot manufacturer which is Comau Company, you saw the Comal labs in the lab-- the Comau robots in the lab, and so-- and also it was very important to attract the students, because of course, you know, I always wish that in my class there is the future brightest mind researcher, but the other 24 students in my ideal class, they have to become professional, they have to becomes engineers, and they have to work for the companies. So to them, you must transfer something which is-- which they can spend in their working environments. So I think in a way, we continued our education program and we easily inserted robotics as a course and so we started the robotics course actually in 1990, the academic year in 1990-- yes, 1990, 1991, was the first course I gave in robotics, and we had lecture notes, and I remember the first year was really fascinating because this was a new course for us, and the four of us, my mentor myself, and the two younger guys who are now full professors at University of Casino, Professor Stefano Cabrini, and at University of Salerno, Professor Pasquale Chiacchio. At that time, I was an associate professor so they were assistant professors, and during the course, no matter who was giving the class, the four of us would attend all the classes with one goal, try to just improve the contents. And we were very, very critical towards one another, because every class we would-- after class we would revise the class contents, and I was changing the lecture notes, and then after two years, I had become-- I became an associate professor, so this became my course, and then I started working on the lecture notes that I wanted to turn into a textbook. And the funny story was that I was looking for a publisher, and we had these lecture notes in

Italian, of course, but I've always thought big in my life. I like challenging, and also having made some experience also of TA in US, at Georgia Tech, I had become accustomed-- acquainted with the university system and then I said, I had the mission to write a textbook both in Italian and in English. So I contacted one publisher in Italy, which was McGraw Hill, which was a subsidiary of the McGraw Hill Companies in US, in New York, and I say, I want to write a textbook in Italian and English, and the editor was almost laughing at me, just, you know, you can't write a textbook in English, because first of all, English is not an easy language to write, and you're not-- it's not your mother tongue. I said, yeah, but my level of English is good enough and I know how to write good technical English, and also I know the courses, the robotics courses taught abroad. And then he was hesitating, I said, okay, let me speak with the editor, and he spoke with the editor of McGraw Hill at the Frankfurt Book Fair, nothing was happening and then I think I contacted people in the UK, and then I got fed of this wait, and then I say, you know what, I will send my proposal directly to McGraw Hill in New York. So the proposal was sent-- at that time, e-mails were not yet popular, so it was the-- sometimes some package, some envelope would come in the mail and you could recognize, this is coming from McGraw Hill, so one day I got an envelope from McGraw Hill Incorporated in New York, and this was the answer to my proposal and the answer was positive. So the proposal had been reviewed, and it was accepted. So they proposed me a contract, and so I signed a contract to write a textbook in English with McGraw Hill in New York. Then I went back to the guy in Milano at McGraw Hill Italia, and I say, I have a contract with your company. They want to translate the book into Italian. And I got the satisfaction of being paid for the translation from English into Italian of my textbook. But this was the kind of honorable [ph?] thing for me, because they had been kind of reluctant, so this was the story behind the textbook. And then throughout the year, the textbook evolved to the second edition, and then McGraw Hill decided to cut off all the advanced titles, because I think they were purchased by some other companies and so then I had to look for a new publisher. And so the second and the third edition of my textbook, which, by the way, is behind here, it came out two years ago with my mentor, Professor Sciavicco and also two of the young guys at the time, Luigi Milani, who was my first PhD student, he's now an associate professor in my group, and Giuseppe Oriolo who was an associate professor working with Professor De Luca at University of Roma La Sapienza and when I think about the time when I was considering taking jobs and university positions in US, then I think at the end of the day, I can say that it's nice that this came out, because this is also a textbook which is a reference textbook in many, in many universities in US. And I think, you know, it's nice that it's been authored by a young person at the time who was seeking for a position in US, but now at University of Naples. So I think it's a way that just the loop has been closed in terms of all the-- if I think about the lecture notes that evolved into this textbook and all the story behind, I can say it's-- I'm quite happy that, you know, this project evolved, and I'm really flattered by the fact that my colleagues in US and Asia adopt this as a textbook for their courses.

Interviewer: And prior to that, what were the other textbooks that were available in Italian in robotics?

Bruno Siciliano: In Italian, none. In Italian, none. There was only a translation. There was a very good book by Fu, Gonzalez and Lee. Lee is, George Lee is a professor at Purdue University, he's almost at the end of his career, he's almost retired, and well he's a dear friend, and this was the only textbook which was available in Italian as a translation, but I have to say that the translation was quite awkward, because apparently it's been translated-- it had been translated, I mean, the part on sensors, and, let's say, intelligence was fine, but the part on mechanics and control was less fine, because the terminology was a little bizarre, because apparently it had been translated by someone who was a professor in computer science and he was less familiar with all the technical terms and the lingo of mechanics and control and mechatronics. So this was-- and I just come to know last week, that this-- Springer signed a contract with a publishing company in China so this is going now to be translated in the Chinese language, and I think they have an initial agreement for 2,000 copies. I think it's by Quian [ph?] University Press, I can't remember the details, but this will be also in Chinese.

Interviewer: And prior to that, I know one of the big textbooks was Lou Paul--

Bruno Siciliano: Lou Paul, Lou Paul is the bible. Actually, Lou Paul, I remember, when I started my PhD, I was studying on-- it's one of the books. It's up there, _____ the green one up there, behind the little robots. That's Lou Paul textbook, which was like the reference. This was a kind of precursor, because it came out in the early '80s, so when I started my PhD in '83, this was like-- this was the reference book and I remember the day in 1995, I was at a symposium in Herrsching, near Munich, and the symposium was being hosted by Garth Hertzinger, actually, DLR, this is the International Symposium of Robotics Research, which is like a top quality meeting. This is very, very-- and it was the first time I had been-- it is only by invitation and was the first time I was invited, and I remember the time in which I was at one of the sessions, and actually I was sitting next to Lou Paul. Lou Paul has not been attending robotic conference since the late '90s, but I had met him. Actually I had visited him once after my stay at Georgia Tech, which was all the network contacts, so I visit him at his _____ club at U Penn. and so I was meeting him again, and I was in a session, and a guy came with a little package from DHL and it was McGraw Hill, and they were delivering the first copy of-- I had goose bumps to remember this, episode, the first copy of the new textbook written by myself and Professor Sciavicco. And I opened the package, and there couldn't be a better time to open this package, sitting next to Lou Paul. This was quite a coincidence and then I decided to give that copy to him, because I mean, there's no better person. And then he came back later with some comments and he liked-- of course, you know, the textbook had been much influenced by-- at that time, there were already other textbooks available, because this

was actually almost 15 years later-- after his first textbook. There were good books by Mark Spong and Vidyasagar. Mark Spong was a professor at the University of Illinois at Urbana Champaign, is Dean now at the University of Texas in Dallas, Dean of Engineering, and the new book is also with Seth Hutchinson who is also very well known in the community, as the current Editor in Chief of the Transactions in Robotics and a dear friend of ours, with Alessandro and others. And there was also a book by Hassan and Zlotin from MIT, and there were quite-- there was also a book by _____ Hoshikawa from Kyoto University, a book from MIT Press. So of course my own textbook had been-- had benefited from all these other textbooks. I tried to give a sort of-- one thing, and of course there was the other, I forgot to mention, but I think it was the most widely adopted book, was John Craig, Stanford University. John Craig was a student of Bernie Roth at Stanford and his book was-- has always been one of the most widely adopted textbooks in the field. John is no longer in the research community. He's been working for-- adapting for SILMA which is a company in the Silicon Valley and I've seen him once in a while, you know, when he shows up to ISRR and all people come to IRIS because it's in San Francisco, so I mean, being a friend of Oussama, maybe I will see him again. So of course my own textbook had benefited from those textbooks in many ways. Of course, you know, being published later, it was also-- for instance, we had a toolbox, a MATLAB toolbox that came with the textbook. This was a nice addition for the fact that, you know, just MATLAB had become sort of the reference software in the field, and so I mean-- and so this was 1995, and now we are, like, 16 years later, and so this is the third edition of the textbook. And of course, in the meantime, those books, those successful books like Craig, and Spong, Vidyasagar and Hutchinson, are also in the third edition, and I think maybe these three books are-- have, like, the largest share of adoption worldwide, and I mean, I like the other two very much, because it's-- but it's-- robotics is not-- it's growing, but I mean, you don't write a textbook because you want to become rich, you want to write about, I don't know, internet or physics or basic subjects, but it's fun. I think the importance of a textbook in-- especially in the field is very important, and lucky enough in the community, we had this huge project, which is the Handbook of Robotics that I coordinated with Oussama Khatib, and that's more like for, I mean, just-- it's good for the people starting doing research, so it's more like--

Interviewer: How did that project come together?

Bruno Siciliano: Oh, the story was-- started in 2002. At that time, we had a good contact with Springer. At that time-- the whole story started in Europe, because in Europe we had a Network of Excellence, funded by the European Commission. This was called EURON. EURON stood for European Robotic Research Network, and one deliverable of that project was a new series of books in robotics. At that time, I established a contact with Springer, because my textbook had just been moved from McGraw Hill to Springer, so I had a good liaison, a good contact with Springer, and then, together with a colleague from the University of Amsterdam, we were invited by Springer in Heidelberg. We went there,

and that time, there were some robotics books published by Springer, but they were scattered in different series, like lecture notes in control information sciences, lecture notes in computer science, but there was no dedicated series to robotics So we sat together and we agreed to launch a new series of robotics books. And this is-- these are the books that you see behind me, the red and blue books. The series is STAR Series, STAR stands for Springer Tracts in Advanced Robotics and so the STAR series started in between the end of-- I think it was the end of 2000, the beginning of 2001, but even though it was European project, I wanted-- I had the ambition to make it international. And then I invited Oussama Khatib, because we always wanted to do something together. Okay, let's do the editorship of the series. So the editors are Oussama Khatib, Franz Groen and myself. And so we launched the STAR series. And the STAR rapidly became as the best selling series at Springer, so there was a really sound start with really good volumes. And a year later I got an e-mail from Thomas Litzinger, who is the Engineering Editor with Springer, and they had just launched the new series of handbooks. And he said, are you interested in writing a handbook on robotics? And I said, oh, that's huge, a handbook is like an encyclopedia, that's-- no, that's-- and then I-- but I was kind of intrigued by the idea, it's like this will be like _____ reference in robotics. And then I just, let me think about, and then I decided, I'll call Oussama. So I called Oussama. I remember I was taking the original phone call, I was about to board a plane, as often, especially since the year 2000, and I call him from the airport, and I told him, should we do it? I just-- I wanted to talk to him before. I could have forwarded the e-mail, but I think it was something that I wanted to tell him in person. So I called him and I say, should we do it? And then our initial answer was positive, and we met in Washington, D.C. actually in Crystal City, because ICRA 2002 was there, so we met with Oussama and the Engineering Editor, so we went to lunch to a nice Italian restaurant, and this was the, you know, like the first stone of the handbook, and we decided to start working on this. And so, and these were six intensive years of work from 2002 to 2008. In my e-mail folder for the handbook, at the end of the project, I was counting something like, I think, 11, 12,000 e-mails stored, which, I mean the first three years was kind of slow, but I mean, I think this was an incredible load also of coordinating all the authors, but I think it was kind of recognition for the whole community, because I think altogether, we wrote a kind of milestone, and it's a kind of piece of 50 years of history of robotics and also our plan is to update the handbook and to work on the second edition to appear in 2013 with multimedia attachment. So the handbook was also, for me it was a way to-- it was an opportunity for a further growth, because there were some fields in which I was not so familiar and so the effort of coordinating all this group of editors and authors and also in terms of the international contacts, it was quite a challenge to get authors from different institutions, from different countries and often the case, from different schools of thought to work together, and because in many cases, it was the first time they were coauthoring something together, so it was a real challenge. And I think, in the-- and also there was a kind of peer review of all the chapters, and in the end, I think this was a nice service, that I think we provided to the scientific community, especially to those new to robotics, that they want to start in robotics. So even though, of course I attach it to my textbook and

those research project, I think the handbook has been, and probably it will be, it will stay the biggest professional project I have-- I pursued in my career, I think. And it's nice that, you know, I had the privilege of sharing this with Oussama, because as I said, you know, we are colleagues, but also we are really, like brothers, close friends to each other, and I think there would be no better opportunity to do something together, other than then handbook. So I'm happy that this has happened in my life, because it is an enrichment in all possible ways, you know, professionally and humanly and in terms of the friendship and in terms of, yeah, the-- really the opportunity of seeing all this gathered into this thick volume, which is behind, it's lying on the table, it's like a very thick tool. And I think I'm kind of worried because, of course, a second edition will have some extension but I think we are already beyond the physical bound of having all this into one volume, so I don't know how it will work. But maybe, I don't know if we can go only electronically, because of course the way to go is like electronic publishing and in fact this has been-- I was getting the figures from the publisher last month, and apparently this has been the book with the largest number of downloads electronically from the Springer website, because the people find it useful to download one or more individual chapters, because they are written in a kind of self contained way, so like whoever's work is willing to start, I don't know, research in medical robotics, come here and the best chapter written by Russ Taylor at JHU Johns Hopkins University and Paolo Dario at the school of Sant'Anna, they are like two of the coauthors of this, so in a way, the authors were clearly selected, possibly _____ to the best people, and we were very surprised that everybody agreed with-- it's a lot of work, of course, but I think once we got a critical mass kernel of the top scientists, it was easy to recruit the others who were missing, because in a way, they felt they want to be part of the venture, and it's all in here, so it's good.

Interviewer: Great, great. Just to go back to the textbook a little bit, subsequent, have there been other Italian language textbooks, or is most of the robotics in Italy being taught in English, or Italian?

Bruno Siciliano: Right now, I'm teaching two courses. One is called Control of the Robot, Robot control, it's in Italian, and the other course is, it's titled, Advanced Robotics and since three years I've been teaching it in English. What happens is, so the first course is compulsory, for all the students, in automation engineering, the second course is elective, so only the students who are really willing to do a thesis in robotics, they choose advanced robotics. But what happens is that most students decide-- the book is available both in English and in Italian, but most students decide to buy the book in English because it's also a good opportunity for them to know the technical language in the field, because one way or the other, they're going to work by using English in their professional career. I have to say though, that Italian, like German and French and Spanish is a kind of major language, in the sense that most textbooks are either translated or available directly in the mother language, whereas in countries like The Netherlands, or Denmark or Sweden, it's often the case that even at the masters level, the books are all in English,

and even the courses are taught in English. So I had-- having decided to write a textbook I couldn't refrain from writing also in Italian, but in my mind, I always wrote first with an English cut. You know, I had in mind to write a book for the international, and also for the-- if you wish for the Anglo-Saxon university system, because the Italian language is also different and it's much more flourished, and the sentences are longer and the style of writing is completely different, so even when I was-- I mean, the Italian version of the textbook is quite unique if you compare, even with the technical books in Italian, because it's intentionally crisp and short, with short sentences, because it was actually conceived as a translation from the English language, and I think the students, they like it this way, because Italian is a language-- I've always live into myself, also being a Neapolitan with a sort of open character and friendly and social, so I used to say, especially to my friends in Germany, that when I work, I'm very German, off work I'm very Neapolitan. So I'm living this kind of dichotomy into my soul, into my innest [ph?] brain and feelings, because I'm very German, very well organized when I work, but clearly, you know, just being born in this city, and having grown up in this city, living in this city, I very much have a kind of open spontaneous and haptic personality, so I live this kind of blend, which in a way could be reflected about the technicality of a language like English, which is almost like a computer language in many ways, and actually, I have to say, I have to confess, that for me, it's easier to give a talk in English than in Italian. I mean, just-- my colleagues, my friends have been telling me that when they come to a conference or a talk, or even the class, a lecture, it's easier for me to-- in English, because it's kind of technical language, whereas in Italian, I think I-- I think I'm consciously concerned about using the most beautiful Italian and the richest and the most flourished, because you can talk Italian at very-- at the different levels, and to talk in a kind of elegant and flourish and appealing Italian, it's not-- it's by no way easy. And so it's even more difficult for a technical field like robotics, so I'm teaching both in Italian and English, and I forgot to mention that we also have a masters here, starting this academic year, so the first _____ masters has taken place. It's actually, the word masters is different from master of science abroad, because a masters here, is a sort of a specializing one year course after the lauria, [ph?] which is equivalent of the master of science. So in order to access our masters, you must already have a master of science of the equivalent of a lauria, so this new master of-- this new masters in robotics intelligence systems, all the courses are in English, the courses, the labs and the seminars, because we also have students coming from abroad. So the whole program is in English, and all the interaction by e-mail with colleagues, and we have a scientific board, is in English, because you know, it's meant to be a sort of international masters for the foreign students, and we have a few foreign students that are studying and are doing this masters here in Naples. So at the end of the day, of course if I go to a-- sometimes I've given public talks to schools, because robotics is also important to take it to the schools and to the younger generations. Two years ago there was a huge science event here in Naples. This is an annual event which is called, Futuro Remoto, literally translating, Remote Future. So it's usually a way to approach people to science and future, and the 2009 edition was devoted to robotics, to robots. We had ASIMO, we had the show with the ASIMO humanoid robot and so Oussama came to Napoli for the

grand opening, and we had the opening with a crowded hall of more than 3,000 people and a lot of kids from the schools, and we gave this talk. I talk in Italian and Oussama, of course, talk in English and I was translating for the audience. But other than literally translating, I was summarizing piece by piece what he was saying, otherwise it would become boring, you know, like the literal translation. Also because he had a lot of pictures and videos, so it didn't really need-- also because it was a kind of dissemination talk, not a technical talk by any way, and then I remember, of course, people knew that there would be the ASIMO show, but I was instructed by the ASIMO team during my talk to simulate I had-- I had cough. I just stopped talking, I had a dry throat, and I was coughing and then I was asking one of the girls, one of the hostesses, like, _____ to bring me a glass of water. And from the backstage, ASIMO came out and served me a glass of water. And even if I had tried this in the backstage, I was-- I got goose bumps, because with this kind of live 3,000 people and ASIMO was slowly walking to me, just bringing me a tray with a glass of water, and it was compliant enough, I pick up my glass of water, and I drank it, and I remember, like, it was my mother sitting on the front row, and she saw this robot and she told my kids, I think there is a child inside the suit, because ASIMO looks like an astronaut. I think this is not a machine, there is a child, there is a person, a human being inside the cover, because ASIMO is quite natural. But this is a sort of kind of mind storm, because in the manufacturing, and in fact, I think some of the-- yeah, some of the big-- the biggest European robot-- the biggest robot manufacturers worldwide, are from Europe and Japan. Surprisingly enough there is no big robot manufacturer in US, despite the fact that robots, as I was saying earlier, were introduced first in US. For some reason the industrial robotics industry was not nurtured in US, and it was soon the case that the attention was more toward, let's say, service robotics and not the traditional industrial applications. I mean, nowadays, I mean, like, two thirds of the world market is still in industrial robotics, although there are studies in the sector that foresee that in 20 years from now, two thirds of the market will be in service robotics. Service not only for advanced new industrial applications, other than the typical automotive, because most of the market is in the car industry, both for the assembly and for the motor parts, and more recently, for the automotive, all the intelligent system, like parking facility, you know, it's the concept of drive by wire, you know, smart cars and smart roads, autonomous vehicles or semi-autonomous vehicles, and things like this. So going back to Europe, we had this strong robotics and automation tradition. But in a way, I felt that in the late '80s and early '90s, we were a little, I think kind of lagging behind the most advanced research in US on field robots and studying around that time in Japan on service robots, because the Japanese started investing in the middle '90s in their humanoids project or approaches where they were developing biologically inspired robots, like, let's say, zoomorphic like the robot dog or the robot seal, Paro, because I think it's a kind of cultural, and also historical and even religious issue behind, because the Japanese have always been convinced that a machine, to be accepted by humans, must have the same shape and appearance of humans, so that's why they have insisted so much in developing a biologically inspired machines. When Sony made AIBO, the robot dog, available, they had orders on internet in Japan, and they sold 2,500 pieces in a few hours. It took six months in the rest of the

world to sell the same number, the same amount of pieces. Because I don't think that, in the western culture, we are prepared to interact with a machine that has the appearance, that has the anthropomorphic or kind of zoomorphic appearance. I think our relationship with the machine is different and we like machine to be a machine and to be clearly distinguished from the humans. So this is one issue and I think Europe had not found yet its way toward advanced robotics. There were some applications of field and service robotics, but in a way they were not mature enough. Things started changing in the middle '90s, also, I have to say, thanks to the financial support of the European Community, because robotics became one of the topical areas for funding and we had the opportunity of carrying out research at the European level, and to cooperate with partners from other countries, because before, there had been some success stories, only on a local basis. For instance, there was a huge project being created after BLR, that took to the development of the lightweight arm that was manufactured by KUKA later, but this is a local success story between BLR and KUKA, which is kind of local reality, and so was the case for ADB in Sweden, with Lund University and also so was the case for us in Italy, working in consulting and working in close cooperation with Comau, we designed the complete control system for the third and fourth generation controllers for Comau and so there was kind of local realities. But I think we were lacking a kind of inter-- inter-lab cooperation, and this was possible, thanks to the support of the European Commission. At the same time, there were some scholars, some researchers who had gained PhD, mainly in American universities and they came back to Europe, and so there was a kind of, I think we were in need of a sort of generation turnover, change of generation, and those bright minds with PhDs in US universities, they came back and they started new labs around in Europe.

Interviewer: And who are some of those names that come to mind?

Bruno Siciliano: Well, there are-- well, there are several. As I mentioned earlier, one of the '59ers is Roland Ziggurat, with-- currently Vice President for Research and Technology at ETH in Zurich, is--

[recording ends abruptly]

[recording begins abruptly]

Bruno Siciliano: --for research and technology at ETH in Zurich. As one is [sic] people of those-- even Antonio Bicchi in Pisa. He is a professor of robotics, University of Pisa. He was for quite a while in the lab at MIT working with Ken Salisbury, another pioneer in our field on dexterous hands. And there are others in France as well. I can't remember the specific names, but I mean there were a number of researchers who started new labs and, in a way, they were able to fill the ideal gap that was existing, I think, between UPM

robotics and the rest of the labs. In the meantime, there were other bright minds that went the other way, because Oussama Khatib that completed-- but this was earlier. This was in the '80s. When he finished, he completed his PhD work in Toulouse and then he went to Stanford. And later we had Sebastian Thrun who moved from Europe to Stanford as well and others who immigrated. But I think a big advantage was also the Robotics and Automation Society of IEEE that allowed this kind of international interaction and with the society all the international conferences. So I think this helped a lot the mobility. And, in a way, there was a sort of international arena where, you know, just we would carry. And, of course, Internet also changed our lives and the robotics is no exception. So, in a way, there were more and more contacts and exchange of visits. For instance, when I went in Georgia Tech at that time I had not an easy time to be accepted as a visiting scholar in the robotics lab in U.S. Nowadays, if I-- just thanks to my contacts-- if I want to send-- I'm sending one of my PhD students now to University of Washington to work with Blake Hannaford on some medical robotics project. So, luckily enough, now we have a network of international contacts and this is also-- it's only at the advantage of the students that they can spend-- but at that time, you know, I-- before email, I was writing my letters to these big professors, big names at MIT, at Stanford, at Berkley, at Carnegie Mellon, but I got no reply because they would not accept me without really knowing me, and maybe they were receiving hundreds of such letters from young students all over the world. Now, I think there is a community and this is favoring the interaction very much. And what we have observed is that-- I mean the modern advanced robotics, mainly field and service applications, now they are pursued everywhere internationally. So I think I'm-- I cannot think of a sort of local geographic context, because we are in a kind of global community and I think it's-- of course, you know, we don't have industrial robot manufacturing in the U.S., but that's for different reason. But industrial robotics is considered to be a solved problem in terms of research. So if we speak about the forefront of research, I cannot see differences, noticeable differences, <telephone ringing> in the sort of--

Interviewer: Do you need to get that?

Bruno Siciliano: No. Can you stop and--

<overlapping conversation>

Interviewer: So let me reframe it. So then Europe-- you were talking about the industrial stuff. But in terms of the research-- there was RoManSy was an early conference that actually also bridged between Eastern and Western Europe.

Bruno Siciliano: Yes.

Interviewer: So what was your experience there and under that--

Bruno Siciliano: RoManSy was unique because it was the only conference where you could meet scientists from former Eastern European countries. So from Russia, from DDR, from Yugoslavia, from Bulgaria, Romania. And there were, like, some bright scientists attending this conf-- including some pioneers, like Professor Vukobratovic from Mihajlo Pupin Institute in Beograd. I think he is recently retired, but he was one of the pioneers especially working on anthropomorphic manipulators, which at that time was quite an innovation. And then-- this was the late '70s. Actually, I started doing research in robotics, doing my PhD in '83, so I just came to the field in '83. But there had already been some conferences. At that time, there was-- the only international conference was called the International Symposium on Industrial Robots (ISIR), which was attended only by robot manufacturers because robotics was not yet kind of scientific discipline. It was just an application in automation. And, actually, the first conference I attended in the U.S. was this ISIR in Chicago in 1983. I was-- I had no paper. I was just accompanying the professor I was working with. And I don't remember there were many, many scientists or many of the names, because RoManSy was a scientific event for the community, even, like, biannual event. And then a major change was in with ISIR. This symposium that I mentioned, which I think the first edition was held in '81 or '83. And this was started from the MIT A.I. Lab community. Lou Paul, Mike Brady, I think Rodney Brooks came late, Tomás Lozano-Perez-- that's another. And then later it was Jean-Claude Latombe, motional planning guy. And they started this series of robotic research symposia, which has stayed throughout the years as a kind of topical meeting every two years. The next one will be actually next month in Flagstaff in late August. So this has always been <inaudible>. And then in '84, we had the first IEEE conference on robotics and automation in Atlanta. And I attended my first ICRA, International Conference on Robotics and Automation [ph?], was in 1986. During the year I spent at Georgia Tech, I attended the one in San Francisco in 1986, which was the third in the series. So, and since then it became a kind of annual appointment. And in the meantime other conference started in robotics. And what has happened in my case, having a control background, I was used to attend mostly the control conference, like CDC, to mention one, the flagship conference by the Control Systems Society of IEEE. This is usually in the December and also the American control conference in June. But this changed throughout the years because I felt that it was-- my community was more like this kind of emerging robotic community. So throughout the years I've attended fewer and fewer CDCs and ACC and more ICRA and IROS-- is the other big conference that we have in the fall-- and all the other meetings. So in a way I felt less a control engineer and more a robotics scientist. And I say scientist because of the exposure and the breadth of our field, which throughout the years has been in need of a lot more beyond engineering and technology. Nowadays in our international project and especially speak about European robotic project, we cooperate with people working in neurosciences. Today we have a meeting with some colleagues and one group in Bologna is working on psychology. And they are also studying the

reactions of monkeys, of primates. And also they are studying-- they are trying to understand better the animals and the humans, and the goal is to replicate this intelligent functions into our robots, into our machines. So it's more and more the case-- and even there are some people working on the ethical aspects of our discipline. There's been a new field, which was started a few years ago. There was a topical meeting in San Remo near Genoa at Villa Nobel and there a new term was coined, was invented. It is "robo-ethics", which is the ethics-- not the ethics of the robots, because the robots by themselves have no ethics, but it's the ethics of those who design, who command, and use robots. And, like, in any other field-- techno-ethics has always been a field. But this is-- and I remember one milestone, which was quite an event for Italy and those internationally, 'cause it was international symposium. In 2008 there was a symposium that was hosted by the prestigious Accademia dei Lincei, which is one of the oldest academy, one of the oldest institutions in Italy, it's almost six hundred years old and actually Galilei-- he was honorary member of this Accademia dei Lincei. And this was the symposium organized there and speakers from all over the world were invited. Oussama Khatib was there. Rassash [ph?] Atilla [ph?] from Le LAAS in Toulouse, Yoshi Nakamura from University of Tokyo was a big name in humanoid robotics. And I was there, too, and Roberto Cordesky [ph?] was there as an expert of science philosophy. And there was even an expert coming from the Vatican for all the ethical and also religious implications of having humans interact with machines. And so the discussion was quite interesting and quite diverse from typical technical meetings. And also there was Guillermo Tamborini [ph?] was also an expert of-- actually he's been leading a project about ethic-bots, about the ethics of robotics to which I also took part. You know, he's a professor in Department of Physical Science here in Naples. And so I mean this is a field where the interaction with other disciplines in sciences is becoming more and more important. I don't know whether the famous prediction by Bill Gates will appear in the Scientific American in the December 2006 issue that in twenty years from now there will be a robot in every home. I don't know if this is true or not. Though I cannot really foresee this anthropomorphic humanoid type of robot into a home. But actually we already have robots here because we have the vacuum cleaner. Roomba is a robot in the home, but I think that there might be another big revolution; like, we give it for granted if I come to your home there is a PC and it's not striking my eye. I take it for granted. The same way as, I don't know, forty years ago when every family had a TV and that was no surprise. And PCs are so, so integrated into our social environments that they are actually a disappearing technology and they are pervasive and ubiquitous. They're everywhere. So the big challenge and the big question is whether robots will become ubiquitous up to the point that I come to your house, there are some robots around, and I don't even pay attention because for me it's granted that I come to your house and there are some robots. I don't think we will find humanoids or bipeds-- or maybe mobile. Mobile robots is more approachable to foresee them into houses. And it's, to some extent, all the kind of intelligent function that we're already implementing in our homes, you know, is-- there is-- I think in English is also called "domotics"? It's the field of domotics. It's like the concept of the intelligent house where you can command all the electronic devices and all the IT infrastructures in your house

remotely. And I don't know if we have a robot baby-sitting and then the mother is controlling remotely through a camera. Technologically, this is viable already, but there are a number of ethical, legal, and societal issues that need to be solved before we could see this kind of ideal invasion of robots in all the social environments in every house. Of course, the legal and social implication were easy to handle for laptops, for computers, but the main difference between a computer robot, there are passing motions and passing motions is I mean it's adding another dimension to the machine. It's not stationary and then when passing motion, it's not as much less-- it's not so obvious they can be integrated into the social environment. So I think this is a big question that is posed not only to the scientists-- I mean to the roboticists, but it's also kind of, if you wish, political issue, whether we really want to have this kind of invasion. But I think it's already happening and I think technologically we are ready for this inclusion of robots in our environment. I think it will take maybe longer than the prediction by Bill Gates to have a robot in every home, because five years have past. So this means that in fifteen years or in twenty- twenty-six years we should have-- I don't know. It's still-- but we don't know because there's been a lot of progress in our field. So I mean the same way as you have an autonomous vehicle, you can have, like, an autonomous mobile robot in our house. You just you go into the refrigerator and take some-- like a coff [ph?], like a waiter, like maid, or you know just doing some kind of simple functions. And actually in the field of rehabilitation, indeed there's been a lot of progress. And nowadays there are machines, exoskeletons that are used currently for the rehabilitation of people suffering from sensory motor deficiencies after a stroke or any kind of-- or even people suffering from Parkinson's Disease. They can be treated with machines in a much more reliable way. Of course, this will be always the therapy is behind, but I think we could exploit the advantage of the machine to be repeatable and to be able to record the progress of the patient in a kind of objective fashion other than being subject to a good or a less good or a bad therapist. So I think machines can be useful. But again, there are some ethical issues. At this future multi [ph?] event there was a demo of a very nice system, which is called HAL. HAL is hybrid-assisted limb. It's an exoskeleton. It's a wearable robot that you wear. This is being developed-- this is developed by Yoshiyuki Sankai who is a professor at the University of Tsukuba and he's also the CEO of a company, which is called CYBERDYNE. So it's a robot that you wear and I try myself. And it's really astonishing because basically it amplifies the electrical signals coming from your muscles and it's capable to lift your arm even if you don't have the power of lifting. So this is very helpful for people confined to a wheelchair having immobility. But again, there are some ethical issues because you can allow differently an impaired person to regain some of the sensory mobile functions, but also you can allow the normal people to become super-humans beyond the human capabilities. And so this is posing a number of issues that are not so obvious to solve. So this is a field where I think the boundaries between technology and, as I say, these ethical, legal, and social issues are very delicate to handle. And whatever answer we're willing to give I think it should be the outcome of quite a long and deep process involving not only the roboticists and the people in technology but also

experts of sociology, of ethology [sic], and psychology and the acceptability of robots by humans and so forth.

Interviewer: So you mentioned that you see robotics as more of a science than simply an engineering field. I wondering if we could have a definition of robotics and how is it related to mechatronics or to these other fields?

Bruno Siciliano: Well, I think yet the best definition of robotics is that which was given at the-- actually this group of people at MIT at the beginning of the '80s is "the intelligent connection of perception to action". And when I'm' asked, "What is a robot?", of course, I can distinguish the machine from the typical imagination as in science fiction, because, of course my kids-- I mean for them a robot is like something like Wall-E or, you know , this kind of imaginary. But I think it's something more than anthropomorphic or kind of biologically inspired machine. Up to the point that-- I give you an example: a sensor network, which you think is nothing to deal with robotics, is by all ways-- and there's a chapter in the handbook-- is a robotic system, because what distinguishes a system to be a robotic system is the complex function and it's the connection of perception to action. And this is a concept which goes beyond the appearance of a mechanical system. Like the autonomous car [ph?] vehicle that I brought to you as an example-- you say, "There is no robot because there is no arm." It's like-- but it's robotics. And, in fact, we have regular sessions at conferences and regular issues in journals dealing with autonomous cars as a sensor part of robotics. So. It's funny, because once I gave public talk about robotics and someone was asking me, "Is the dishwasher a robot?" Because, you know, you can extend this definition and you kind of-- and then I said-- I hate to disappoint this person in the audience, I say, "No, because actually it's a kind of repeatable program. It's a machine, but there is no intelligence interaction within the environment." So what really distinguishes a robot is the capability of interacting intelligently with the environment. That's why the industrial robot was dead at the end of the '70s and early '80s, because all the problems-- because industrial robot is quite stupid in the sense that it does the same work just over twenty-four hours, three working cycles, and there is no intelligence, no interaction. If something happens, then the robot can kill a human. Or it's just kind of pre-programmable and repeatable machine. What really distinguishes robotics is that you have the interaction between the system and the environment. So it's-- although you might argue that in the late '50s, in the early '60s, when robotics started, they started from sort of emerged, on one hand, of numerical control machines, on the other hand, of visionary people working in A.I. So for the people working in A.I., in cybernetics, an industrial robot was still a sort of challenging machine yet to come. So in a way it's a sort of time-evolving definition and we can't ignore this. So for me industrial robot is no longer a robot, although the new, advanced industrial robots compared to the old robots, now they work in close cooperation with humans because we made them safe and the humans can share the same workspace as the industrial robots. So, in a way, it's intelligent robot because it's interacting in a kind of reactive fashion with the humans. So I

think that it's not easy to identify a robot because, of course, the typical conception is a mechanical arm or is a mobile vehicle or, if you wish, could be a mobile manipulator. So an arm on a mobile platform. So when I teach my students of my robotics class, of course, I bring along the example of when I speak about the definition of motion, which is intrinsically robotics, I typically visualize motion in terms of mobile platform, of legs, of crawlers [ph?], of arms, or wrists, of hands, because that's typical. But then I also argue that a sensor network is a robotic system because it has the particularity of distributed systems who are distributing intelligence and share of resources that the typical mathematics and the typical tools to describe those systems are also typical of a real team of robots. Like when you have a swarm of robots-- I was missing the word-- a swarm of robots of real mobile robots, because it's the same kind of problem. So this kind of-- this has happened at people working on sensor networks when _____ robotics methodologists and we discovered a new application which was beyond the boundaries of the typical distributed mobile robots. So this is happening very much in the field. So I think the modern definition-- because if you take the original definition, which was established by the RIA, Robotic Institute of America, of the robot being a reprogrammable machine, blah blah blah things, which was the typical definition for the industrial manufacturing environment, is no longer a good definition for the modern robotics. And I think the definition of robotics, other than robots is much better, and then robotics, as I say, this is defined as the science of the intelligent connection of perception to action. And this is a sort of naturally evolving definition which can be seen, can be recognized, in many applications, which as I say to our-- even in the social sys-- is in fact most of the work-- take, for instance, you mentioned earlier in our briefing, you mentioned about evolution in robotics. And people are studying the behaviors of a swarm of insects also to understand better the social behavior of and to try to replicate this behavior into the intelligent behavior of real [ph?] robots. So this is really a science which is evolving and is involving people from other fields. So this is very much the case. And I think the modern definition is still capable of capturing these aspects because it doesn't focus on the apparatus, on the mechanical apparatus, which often you confine into real robotic system, but it's not even without the mechanical apparatus you can have the statistical [ph?] problems of objects of passing motion like flying rock-- flying lakles [ph?] are, by all means, is a robotic system because of the peculiarity of the system. And that's why the education of students in this field is becoming more and more challenging. And, of course, you can approach robotics from mechanical engineering, from electrical engineering, from computer science. But what I used to tell my students, especially the ones studying PhD, try to open up your mind and just look around. And actually, I'm lucky that in my team, I have a good mix because before we were recruiting only students with a degree in double E. Right now, I have one student with a degree in automation engineering, and another, she has a degree in biomedical engineering. I have another one in electronic engineering. I have another one in mechanical engineering. And I have even another one with a non-engineering degree. She has a degree in sciences, in physical sciences. And, in fact, she spent six months now in the lab at UCO-- at University Paris's-- University of Pierre Marie Curie in Paris, working with a group of people doing work on the psychological aspects of

interaction between humans and robots. So, she's been working that field. And she's still doing a PhD in engineering with a non-engineering degree. So, this is the evident case, proof that we are knit. And it's nice to have a team in which we have this kind of complimentary and different backgrounds because this adds to the team and makes research more lively, more interactive, and more fun because, as I used to tell my students, have fun. This is the best time of your-- I mean problems will come later.

Interviewer: So, who are some of your other PhD students who are now working in robotics, either in industry or in academia?

Bruno Siciliano: Yeah. I have to say that the PhD system in Italy, for many years, has been meant as the gate to an academic career because it was a system that allowed recruitment of several generations of PhD. So, after me, I have to say that all my students, now they are-- all my PhD students of the first ten years, now they are all faculties. And actually, the Prisma [ph?] lab that I mentioned, actually it's a group gathering six or such teams. The mother team is in Napoli. And then we have other teams in Salerno, which is near Napoli, in Cassino, which is half the way between Napoli and Roma. There is also a second University of Napoli. Naples has five universities. And not many people know that Naples has a student population of a hundred and ten thousand students, out of a population of one million two hundred. So, one every eleven people living in Napoli is a student. So, is a big university town. And despite what the media like to write about, and the-- so, and then there's another former student of mine who is an associate professor at Universita della Basilicata in Potenza. And then there is my mentor who moved to Univers-- to third University of Rome, Professor Sciavicco [ph?], who is soon now to retire at the end of this academic year. So, in the years, the PhD program has changed for two main reasons. One reason is that it became a kind of established degree. And finally, after fifteen, twenty years, it started to pay off as a higher academic degree, which was allowing people with PhD to get a better position in industry. The guy who walked into my office this afternoon is a former PhD student of mine who was a post doc with me. And now he works for a company working in energy and automation. And lucky enough, he was given a sort of managerial position. So, there was a recognition, both in terms of seniority and also financial, economically for his salary because initially, when I was doing time my PhD, I had made my choice already. And I knew that I had no choice but to pursue an academic career track because if I would go to industry, four years, five years later, industry would consider me as a kind of old graduate because there was no recognition whatsoever of this higher academic degree. So, now the world has changed. And also, this is thanks not only to the fact that companies have understood in Italy, and also because it's more like an international European perspective because now all the schools, all the universities in Europe, they-- just the PhD, and there's also the system of credits, so we can easily compare the degrees between Germany, and France, and Italy, and so forth. And also there is more mobility. So, the students with PhD can also apply for a job abroad in, say, in Germany or in France. And so, this is helping. And,

at the same time, that being especially in field like robotics, quite a few spin offs and start ups that were stemmed from the academic clubs, for instance, the group of Professor Sigvat [ph?] in ETH Zurich. ETH is the institution in Europe with the highest success rate of start up companies. They have the record in Europe. And so, they started working for those start ups or for small or medium enterprises. And so, there've been career-- professional career opportunities for them. And that's why now in my team, I have about-- currently, I think I have seven PhD students. Whereas, when I was a PhD student, I was alone. And usually, we would recruit after me. The students were recruited not even every year because, in a way, there was a kind of time scale to allow for these PhD students to grow up and to look and to run for academic positions. Now, of these seven PhD students, maybe only one will ultimately stay with me as an assistant professor. The others will actually-- I already have two as a post doc who will work with me for another number of years. And then, either they leave and they go elsewhere, just eventually outside research, outside academia, or maybe just like one will become a faculty like in U.S. and like in many other systems. So, this has also contributed to, in Italy, and also elsewhere in Europe, to carry out more research because we have this funding from European commission. At the same time, I have, I should say, fewer reservations to recruit a new PhD student because I don't have to promise an academic career track because I know that working in a good group like I think it's mine, this can pay off. And they can go outside. And they can find a good job when they leave university, say, after PhD or after post doc. So, this has also contributed to the sort of growth of the PhD program itself in Italy. At the same time, and also as I say the mobility at the European level, like-- and I have two students of mine, one is doing a PhD in Spain after the masters. And another is doing a PhD in Germany. And at the same time, now for one of my in European project, I'm in need of some expert post doc. And I just opened now a call for post docs. And I sent it to the European distribution list, and even to the robotics worldwide list. And this morning I got an application from someone who has got PhD from University of Florida and I think is currently working at NASA JPL. So, I mean it's much more mobility. So, people come and go. And I think this has increased the- - has given impetus, I think, to research worldwide in the various labs. But I've always been convinced of this kind of international dimension. And from-- on one hand, I hate, I have to say the typical Italian mentality because especially in the Italian university system, the classical stereotype-- the classical pattern is that you carry the bag of your professor for many years until then you become an assistant and become a professor. And I hate this because the system abroad is different. Actually, people getting a degree in one institution are really encouraged to leave and to move to another institution because this really enlarge, or gives-- opens your mind. And then maybe you can come back later. I think in Italy, we have suffered a little bit from this kind of just bag carriers, just little translating from porta borsa. And I think we are now more in the sort of European, international dimension. And take, for instance, the Italian Institute of Technology in Genoa, most of the staff is from outside Italy. And that's the way it must be, I think because I think it gives more opportunity to the lab to grow and to-- and also gives even to the students, more opportunities and to look around. And for those that will leave academia, they have wider

scenario. And they have more opportunities than just being on track and working, just kind of narrow scope only for one lab.

Interviewer: Have you been involved in any start ups or any strong collaborations with industry?

Bruno Siciliano: Not directly, in the sense that, for several reasons, I think I've always been feared-- worried, or maybe feared, I should say, because it takes quite a bit of time and energy and also-- well, money. I could have found the money. But I've always been I think-- I don't want to say a purist, but I think you have to make a choice. I'll give you just the example. The service I have given to the society, I'm speaking about <inaudible> Society, I couldn't have done this while maybe just giving birth, giving rise to a start up. So, in a way, I consider myself to be a kind of pure academician. And I haven't wanted to challenge this. It's also true that in Italy, it's less easy than maybe elsewhere like to find a venture capitalist or a business angel. But I know of some, a former student of mine, but not in robotics. Then they have-- just they wanted to involve me, but in a way I didn't want to be involved because also I am quite much involved into all the academic programs and activities. And I thought that I would not have time for this. And I think just even Usama [ph?] is about same story. Several of these students have given rise to start ups, but in a way, has always been on the academic side of the river. I don't know. I'm trying to encourage some of my current PhD students and post docs to give rise to start ups. And I will be advising them. But I thought that I never had the time myself to be involved on the front line of this. It's a choice. I mean it's-- of course, money's important, but I like my way. In a way, it's like--

Interviewer: Where have you gotten your funding over the years, primarily?

Bruno Siciliano: Lucky enough, in the latest seven, eight years, from the European Commission. If-- I mean, as an Italian, I have to say this. Italy is not investing-- I mean this is quite well known, is not investing enough into research. We are one of the countries in Europe with the lowest percentage of the gross income spent on research. I can give you some figure of comparison. The basic research is funded by the Ministry of University Educational Research at the level-- there are some projects which are called National Interest Research Projects, and the budget for one area, which is industrial and information engineering-- so, it's a pretty big area, robotics is maybe two percent of this area-- no three percent-- less than five percent for sure of this huge industrial and information engineering. The funding from the Ministry is about ten million euros every two years. This is peanuts. So, they give-- this is like seeds money, rain money. They give a little bit to every group. And most people in academia are happy they get funding of forty, fifty thousand euro. They get a couple of computers, two or three trips. They can't

even pay a PhD student, but they're happy because normally PhD students-- there is also _____ grants from the university. Actually, my students, one or two they got academic grants. And the others, I pay on my projects. But people are happy with this. But how can I do forefront research with this kind of little money? So, lucky enough in robotics in Italy, we contribute to the Seventh Framework Programme of European commission with seven percent. This is our share, as a country, as Italy. But lucky enough in robotics, we get back, in terms of funding, more than eleven percent. So, eleven percent of the money given by the European commission for robotic project in Europe goes to Italy. So, there is a kind of a-- more than fifty percent gain into the game, whereas in other areas we are suffering. We give more to the European commission. We get less back. So, I'm happy that-- I don't want to say anything bad about our current prime minister, which has been involved in a number of scandals, but of course, as a scientist, I'm quite discussed of being represented. And I want to say this, and I have said this in many public occasions. But I'm happy that a ton of money gets washed in Brussels and Luxemburg because the top scientists in Italy, they get this money back and even more. I couldn't carry this forefront research just with the-- I couldn't afford having seven, eight PhD students and pay post docs. And I'm paying two secretaries because we don't have a secretary from the university like, for instance, in U.S. So, I'm happy that I can compete. And this is only thanks to this European funding. Besides European funding, we also have contract with companies. But that's a different story. That's not public money. And some of this money is consulting. And I am full time professor, so whatever consulting I do through the department. And again, it's a choice because you can be part time and then you have no limits in the money that you can make as a consultant to the-- we're also consulting for the companies, but through the university. And then we're just happy that we have this. And actually last Thursday, I was in a meeting in Luxemburg, European Commission. And this was a high-level meeting, a strategic meeting in preparation of the Eighth Framework Programme, which will start in 2014 until 2020. And I learned the good news that there will be a program, which is called-- this is public news now since two weeks ago. There will be a challenging program what will be called Horizon 2020 in Europe. And this will be a big challenge. And the good news I heard is that the funding will be for the Eighth Framework Programme for eighty billion euros, current money, which with inflation might even be ninety billion euros by 2020. So, the current framework program, the Seventh Framework Programme, we got a total funding of FP7, I think of about fifty-six billion. So, despite the economic downturn, the recession, I think that Europe is investing into research. And so, this is good news for research, meaning that I think they understood that to compete at an international level, you need to invest into research. And also there is a non-negligible component into education because also in Europe we have the Erasmus student exchange program. So, I used to send my students to the best universities in Europe. And also I welcome now some of the students coming to study here. The problem is the language because Italian is only spoken in Italy. And so, most of the mobility is usually with Spain because of the-- it's not difficult for a Spanish student to understand Italian, Italian students likewise, to understand Spanish. It's a little bit more difficult with German because German is so diverse. And the French is okay, and then-- but most students they

go to Denmark, Netherlands, Sweden-- or not Sweden, but to U.K. because there they can find courses regularly taught in English. So, it's much easier for them. So, I think there is now a strategic program in Europe, which will facilitate the advancement of science. And robotics will-- hopefully will play a big role into this. We've got in robotics, in Framework Programme Seven, about four hundred-- so far, it's four hundred million. I think in the end we'll be five hundred with the next call, five hundred million euro to European robotics. And this is good money. So, if you compare-- and I'm bringing to my department more than one million euro funding a year. Now, going back to the concept earlier, my salary is still the same in the sense that I cannot even pay for my summer salary because of the academic rules. I'm trying to change the system now and to allow-- especially that I want to give more money to my young post docs because I have to be appealing to them and not to go outside. And I want to pay them more than the system allows me to pay. So, hopefully I will-- it's kind of almost political battle. I'm fighting with the administration these days and hope to succeed as all the-- most of the battles I've-- and yeah so, but lucky enough, we have this huge funding. So, how can I compare my one million euro only on my group with the ten million euro that they give-- or all the five million because ten million for two years that the whole Ministry gives? Of course there is no comparison. If I had to do research with the fifty K from the Ministry-- actually I think last week I came to know that my project with the Ministry has been funded. I don't even remember how much it is. Probably it will probably be like <speaking French>, to use a French expression, like peanuts in a sense of some kind of cash money for consumables because that's-- that's why there are certain privilege areas, and robotics is one of this, where the Italian researchers can be in the front line, the forefront of research. And this is thanks to European funding or some different local realities like Italian Institute of Technology in Genoa. They have direct funding from the government. But this is outside the Ministry, the Minister of funding. Or thanks to the well known and well established reality like, for instance, the School of Sant'Anna in Pisa where my colleague and good friend Paolo Dario [ph?] was able to raise money also from the region to find some extra sources of funding. Otherwise, you can't keep a group of many-- you cannot do the kind of competitive research with-- but even in U.S. is the same story because the National Science Foundation doesn't fund robotics any longer and most of the projects are with the DoD, with DARPA. Although the good news for our American colleagues is that there is an Obama statement that will be a huge program now devoted to robotics. This was announced in the news I think two weeks ago. This is the effort of Henrik Christensen in Georgia Tech with other colleagues like George Bekey [ph?] at University of Southern California, Matt Mason at Carnegie Mellon, and Vijay Kumar at University of Pennsylvania. So, the four of them have succeeded to take robotics to the Congress. And now finally this big funding has been approved. And, as a European, I was happy that Henrik, coming from Europe, as exported to the European model of networking among American universities. And he has succeeded because this is the way that-- I mean the results now that we have good funding from European commission have not come by chance because they are the result of years and years of work and lobbying with the European Commission in Brussels, and also to show that we had great potential in

Europe in terms of the network-- EURON, this robotics _____ network, allowed us to know one another among the labs and to have kind of critical mass-- of course there are thirty top labs in Europe. And EURON currently counts two hundred and thirty members of academic clubs. Thirty of which are very active. The other ones are dormant in the sense that they are part of the network, but they are not really involved into the European-- but little by little, especially now with the new member states of the European Union, I think we got more and more involved. And also we have some funding opportunities like the one I was mentioning to you earlier during the briefing, like this Echort [ph?] project that allows also small labs and small companies to have access to European funding in a way that this can allow them to grow and to have cooperation with more established labs. And I think in Europe we are quite attentive to this because I think we believe into the-- and I think science is one field where the European Union is more perceived than maybe like in the polit-- well, of course, financial, with the euro, with the currency, this was a big conquer. And it's-- and I think science is one field is a lot of interaction overcoming the typical political barriers, which still exist despite the financial unity under the euro currency. And, of course, science is a field where we-- I think the European dimension is really felt by the actors, by the stakeholders of robotics and many other fields. So, we are happy that this is happening because I think that's the only way to compete with the top research in North America and U.S. and Canada, as well as with top research in Japan. But is not only in Japan because Korea is growing. And in five, ten years it will be China. That's for sure. So, they have a gradient, a growth gradient, which is extremely steep. And they are already quite active in terms of conferences, in terms of publications. Of course, there are some risks related to this. And also, it's not easy because they have a lot of governmental control. When we organized our _____ conference last May in Shanghai, we had to overcome some political obstructions, which were mainly caused by some governmental control of all events. But I think they are quite open now. And I think in five, ten years, they will be big actors into the science arena worldwide, I think.

Interviewer: What do you see as the biggest technological and scientific challenges facing robotics over the next five or ten years?

Bruno Siciliano: I think the-- our robotics systems are becoming more and more—

[recording ends abruptly]